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Original Communication

Virtopsy – The concept of a centralized database in forensic medicine for analysis and comparison of radiological and autopsy data

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Abstract

Recent developments in clinical radiology have resulted in additional developments in the field of forensic radiology. After implementation of cross-sectional radiology and optical surface documentation in forensic medicine, difficulties in the validation and analysis of the acquired data was experienced. To address this problem and for the comparison of autopsy and radiological data a centralized database with internet technology for forensic cases was created.

The main goals of the database are (1) creation of a digital and standardized documentation tool for forensic-radiological and pathological findings; (2) establishing a basis for validation of forensic cross-sectional radiology as a non-invasive examination method in forensic medicine that means comparing and evaluating the radiological and autopsy data and analyzing the accuracy of such data; and (3) providing a conduit for continuing research and education in forensic medicine.

Considering the infrequent availability of CT or MRI for forensic institutions and the heterogeneous nature of case material in forensic medicine an evaluation of benefits and limitations of cross-sectional imaging concerning certain forensic features by a single institution may be of limited value. A centralized database permitting international forensic and cross disciplinary collaborations may provide important support for forensic-radiological casework and research.

Keywords: Virtopsy; Forensic medicine; Radiology; Database; Digital autopsy; Post-mortem

1. Introduction

In recent years, forensic radiology has experienced intensive and rapid progress that is supported by the development of clinical radiology.[1] Recently implemented cross-sectional radiological and optical surface documentation methods have gained recognition and applications in forensic medicine.[2–6]

Currently, we use multi-slice computed tomography (MSCT), magnetic resonance imaging (MRI) and a 3D surface scanning for objective and non-invasive documentation of internal and external body injuries of selected cases in addition to conventional autopsy.[3–6] Although these methods are not yet routine in forensic medicine the reported results are promising.[2]

After gaining experience in the growing domain of forensic cross-sectional radiology and optical surface

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documentation within the Virtopsy project at the Institute of Forensic Medicine in Bern (Switzerland), a problem in the validation and analysis of data acquired was established. Forensic-radiological examination data are once assessed regarding forensically relevant findings and then stored on CDs. Some data are lost and some remain unused. In the first three years after the implementation of cross-sectional imaging in forensic medicine within the Virtopsy project, about 13 cases (range 6–20) per half year were examined using MSCT and MRI. In the first six months, since our institute acquired its own computed tomography (CT) scanner (Emotion 6, Siemens, Germany), we have already examined around 50 cases with the CT scanner alone. This is approximately one sixth of the whole year's deceased cases at our institute. The expected number of deceased that undergo forensic-radiological or 3D optical surface documentation, and thus the number of datasets to archive, is rising with each year.

In collaboration with the Institute for Evaluative Research in Orthopaedic Surgery at the University of Bern (Switzerland), we attempted to address this problem by creating a database with internet technology for forensic cases. The following presents the goals and concept of the centralized virtopsy database for use in forensic medicine.

1.1. Goals of the Virtopsy database

With the implementation of new documentation tools in forensic medicine, such as cross-sectional and optical imaging, the need of a prospective and capacious database has emerged. It is anticipated this database will have potential in or serve as a:

1. digital and standardized documentation system for forensic radiological and forensic pathological findings in forensic medicine that is accessible 24 h a day and 7 days a week by all registered users via internet;
2. tool for comparison of the radiological and autopsy findings, i.e. evaluating the accuracy of the virtual autopsy approach (radiology) in comparison with the in the community currently accepted gold standard autopsy approach: validation of forensic cross-sectional imaging as a non-invasive examination method in forensic medicine;
3. forensic-radiological, pathological and epidemiological information source;
4. means for collection, archiving and distributing anonymous medical data both online and offline;
5. tool for the continuing research in forensic medicine;
6. tool for the continuing education of young specialists in forensic medicine and especially in forensic cross-sectional radiology;
7. tracking tool for quality control;
8. conduit for the cooperation and exchange of experience between forensic institutions at on national and international level (telemedicine);
9. instrument for standardization of the service, education and research in forensic medicine, hence being a step towards successful accreditation.

1.2. Background

On the basis of pioneering work in the field of orthopaedic and trauma documentation initiated by Professor M.E. Mueller in the 1960s, the Institute for Evaluative Research in Orthopaedic Surgery of the University of Bern has advanced the concept of centralized documentation to enable the establishment of international registries.[7–9] Over the past 5 years various additional clinical databases, primarily for surgical specialities, were created.[9]

In 2000, a new methodology in centralized data management was built and devised using the latest innovations in medical informatics by the Institute for Evaluative Research in Orthopaedic Surgery.[9] The outstanding advantage of this technology is that the end user is not required to purchase, install, or maintain any specialized software or hardware. All technical servicing is performed at the central server (Fig. 1). Accordingly, examination protocols can be easily and quickly distributed to a large user community, while data retrieval and analysis are conducted centrally. Such a system enables an easy setup of local, national or even international registries. For participation, end users only need a personal computer with access to the World Wide Web and a user account. The need to purchase hardware only arises when a participating hospital would like to keep full control and hence responsibility for all sensitive data sets (see below in Privacy Issues).

The workflow-based database validates the quality of the collected data. All validation checks are performed at the point of data entry so that the user cannot submit incomplete, invalid or inconsistent data sets. Error messages pointing out missing or contradictory answers are displayed and the data cannot be saved until all of the preprogrammed validation criteria are met. This setup guarantees an accurate, integrative, valid and competent data sampling and eliminates the need for retrospective data correction. The enormous human and financial resources needed to key in paper-based data and to correct and complete invalid datasheets is saved using modern internet and computer technologies.

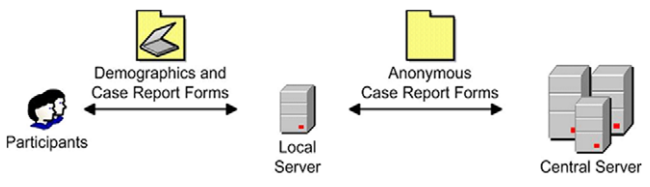

Fig. 1. The order of the data exchange within the Virtopsy database. Note the anonymous data exchange between the local server at our institute and the central server at the Institute for Evaluative Research in Orthopaedic Surgery (University of Bern).

2. Methods

2.1. Technical setup

The electronic documentation system employs a multi-tier client-server for data collection and storage. Integral to this system is a central Oracle 8i database, which stores protocol question/answer definitions with validation rules, as well as collected datasets.[7,9] Several information technologies such as PHP/PERL/JAVA scripting and Java are utilized in the overall architecture of the system, providing a balance between development efficiency and application performance. Furthermore, a web content management system is utilized to allow parts of the interface to be managed by non-technical staff members.

2.2. Questionnaires

Based on an extensive questionnaire for pathological autopsy from the local institute for pathology, the statistic questionnaire from our institute as well as on the latest textbooks in forensic medicine questionnaires with forensically relevant findings were created and in detail tested by all board-certified pathologists of our institute regarding their completeness. Substantially, the criterion for the creation of the questionnaires was the intake of all forensically relevant findings to all body regions and tissues (Fig. 2), to allow for a not time-consuming and complex but still relatively detailed documentation of forensic findings. Also general information such as the chronology of incident, ante-mortem radiological examination, death, post-mortem radiological examination and used MRI sequences of a case should be ascertainable using the questionnaires.

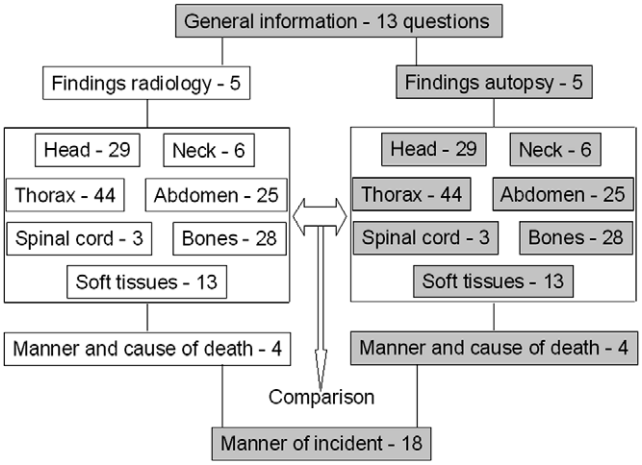

Fig. 2. The diagram shows the subforms of the Virtopsy database including the number of the questions and who is responsible for their completion. The white marked subforms should be filled in by the forensic radiologist and the grey by the forensic pathologist. The parallel filling in of the same questions by the forensic radiologist and pathologist, except for the general case information and the questions about manner of incident that are to be answered by the forensic pathologist, allows for comparisons of the cross-sectional radiology and the autopsy data, to see how many and which findings are detectable using which method.

3. Results

3.1. Case report forms

Case report forms of the Virtopsy database are broken down into so-called subforms, which represent the amount of data that has to be entered and saved in one documentation step (Figs. 2–4).

The first three subforms contain general information on a case and on performed investigations and a steering-question in which both the forensic radiologist and forensic pathologist define the affected body parts of a case (Fig. 2 and Fig. 3a).

With this steering-question, the consecutive subforms (head, neck, thorax, abdomen, spinal cord, soft tissue, and bones) are only pulled if they are needed for a specific case. They are all then to be separately filled in by both the forensic radiologist and forensic pathologist (Fig. 2).

The last two subforms of the database contain questions for the forensic radiologist and forensic pathologist, accordingly, about manner and cause of death (Fig. 2 and Fig. 3c).

Incomplete subforms are not accepted by the underlying validation and completeness checks of the system. Subforms can be reviewed and corrected as necessary until the entire form is complete. Once the entire case has been entered it can be "submitted" to the central server (Fig. 1). After a case has been submitted it cannot be altered anymore.

Each form can be printed out in a rough question–answer format and be added to the case files. A printout of a completely filled out case takes a maximum of five A4 pages and includes a maximum of 157 forensically relevant questions for forensic radiologist and pathologist. The two investigators, the forensic radiologist and forensic pathologist, complete the same questions, thus, future comparisons of radiological and autopsy findings are possible. Based on these comparisons the evaluation of the accuracy of the virtual autopsy approach (radiology) in comparison with the in the community currently accepted gold standard autopsy approach can be done. Documented cases will allow to calculate in percent how much of the findings are visible using radiology in comparison to the autopsy and vice versa. Additionally to the questions of forensically relevant findings, there are 31 questions including general case information and the questions about manner of incident that are to be answered by the forensic pathologist.

An additional documentation tool includes a possibility of archiving of picture information to comprehend the case documentation. Radiographic, computed tomographic, photographic, or other images in TIFF or JPEG format with a maximum size of 5 MB per picture are accepted. Up to six picture files can be linked to each case. The central server is fitted with a picture archiving and communi-

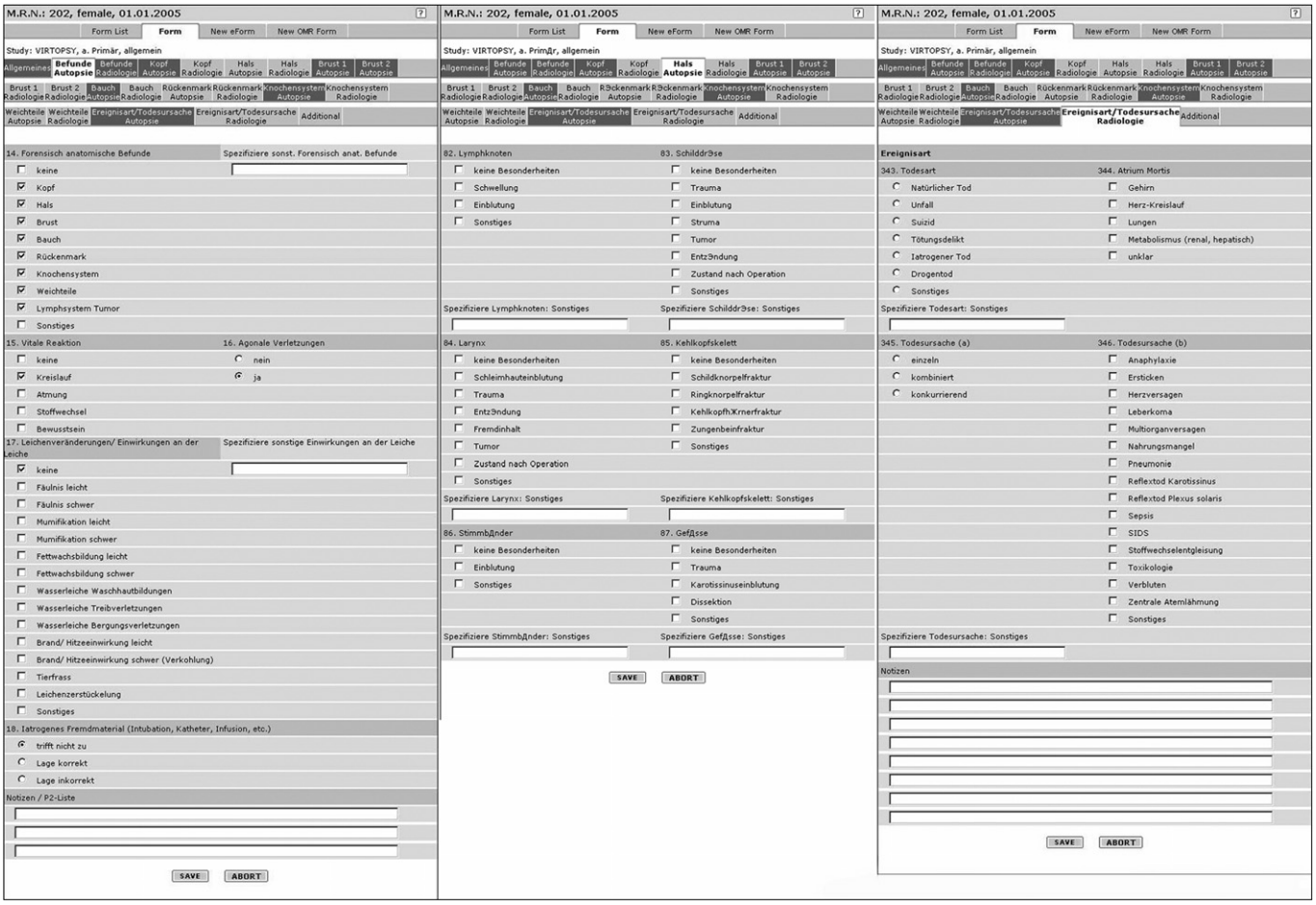

Fig. 3. An example of three subforms: (a) the subform exists in a duplicate to be filled in by both the forensic radiologist and the forensic pathologist. It contains a steering-question to define the affected body parts of a case and some general information on a case; (b) the subform exists also in a duplicate to be filled in by both specialists. It contains questions to the neck; (c) the subform contains the closing questions for the forensic radiologist about manner and cause of death of a case.

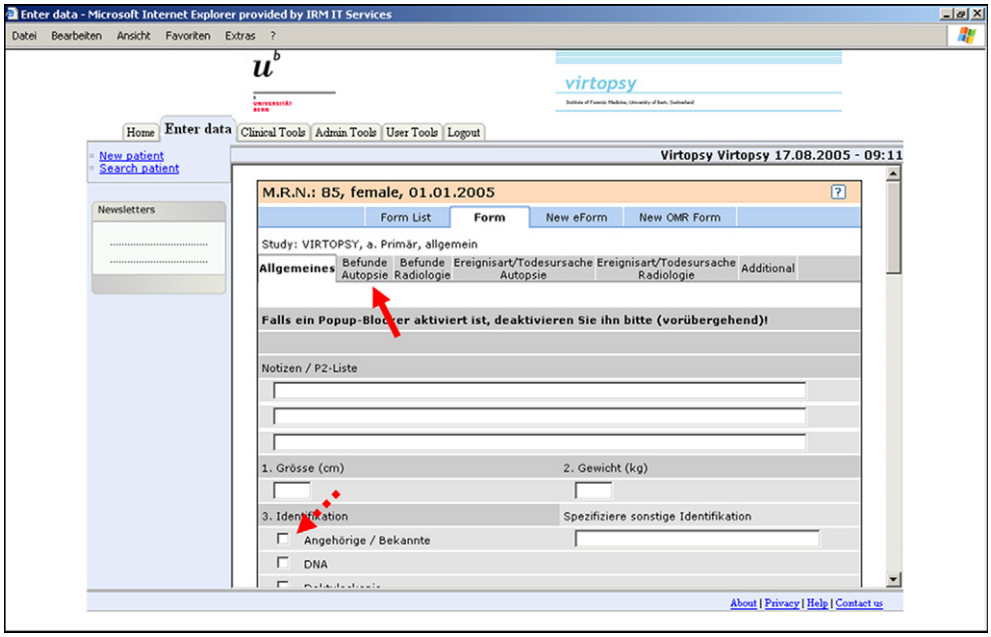

Fig. 4. The screenshot demonstrates the web site of the Virtopsy database with a number of subforms (solid arrow) and questions (dotted arrow).

cation system (PACS) allowing for automatic reconversion of these images into DICOM (Digital Imaging and Communications in Medicine) format to meet the diagnostic standards of the American College of Radiology, and displays them via the online interface with various functionalities of picture manipulation (brightness, contrast, black–white inversion, zooming, and so forth). Importantly, the images should not contain any personal information due to the anonymity protection.

3.2. Enter of the own data

Currently we have retrospectively and prospectively entered over 150 forensic cases. A prospective documentation of a case takes 20 min on average, depending on its complexity (range 15–25 min), and a retrospective entry needs up to 10 min more, since the findings should be first searched in the case files. About one half of the time is used by the forensic radiologist and another half by the forensic pathologist (Fig. 2).

4. Discussion

4.1. Privacy issues

The exchange of medical data sets across state borders via the World Wide Web presents important challenges with regard to the protection of data privacy. Participating users are usually uncomfortable sending data to a central server that is not located within their institution. Forensic medical institutions, which are dealing with different kinds of delinquency, are especially problematic in this view.

For this reason a local web server that acts as a filter between the user and the central database and enciphers all identifiable information was developed by the Institute for Evaluative Research in Orthopaedic Surgery at the University of Bern[9] (Fig. 1). With such a server each participating institute can access the system through their own web site (Fig. 4), administer the local application autonomously, and hence keep full control and responsibility for all sensitive data sets.

Such a server with individual specific features for forensic medicine was purchased and installed within the Center for Forensic Imaging in Bern for Virtopsy research group (Fig. 1). Thus, only anonymous case data are passing on to the central server. All identifiable case information, such as demographic data and autopsy date, are not sent to the central database, but are stored on a local server at the Institute of Forensic Medicine. Among all centralized web-based registries at the Institute for Evaluative Research in Orthopaedic Surgery of the University of Bern, the Virtopsy database was created under the strictest privacy demands.

4.2. Unity and diversity of a database

Currently, a centralized web-based database was implemented within our institution (Figs. 1–4); however, the long-term objective is the establishment of this database for international use. The biggest obstacle in establishing such an inter-institutional collaboration is the heterogeneity of interests and ideas regarding contents and techniques for documentation. Furthermore, the variety of pathological findings, as well as the interpretations and section techniques can further complicate such an endeavor.

On the other side, there is no doubt that the internet represents the ideal and cheapest solution possible to network all users, and to gather datasets in a central database. Moreover, as already mentioned, no costly hardware and software purchases are necessary to run or maintain the installation, since system upgrades and maintenance are only conducted at the central control unit. Participating institutes incur a flat cost of $50 per month. The documentation fees are calculated per department, regardless of the number of entered cases.

In contrast to the clinical medicine, a standardized questionnaire for case relevant findings is something unusual in forensic medicine. Perhaps the variety of forensic findings and the individuality of cases complicate any standardization. After the screening of the medical literature no capacious questionnaire for forensic findings were found. Thus, new questionnaires with forensically relevant findings for the use in the database were created and tested in our institute (Figs. 2,3).

The generally accepted medical terminology was used for the questionnaires, thus the forensic-radiological part of the database can be filled in by a resident in radiology and the pathological part, accordingly, already by a resident in forensic medicine. Of course, the accuracy of entering data and the entering time directly depend on the professional experience of both specialists. For the evaluation results of the Virtopsy database please see forthcoming papers.

Regarding the length of time needed to enter a case, which mainly results from the relatively large questionnaire and the bidirectional communication with the central database for validity checks, we are aware that it is currently unsatisfying. Ongoing improvements in the software will further increase the speed of the validation routines in the future.

The present language of the database is German; however, the translation of the questionnaires in other languages required for future international use, such as English and French, is a part of current work. Because the active fields in the questionnaires refer to a predetermined matrix in the central server application (like e.g. in the Interpol ''Disaster Victim Identification'' protocols) – the use of forms in different languages and their analysis is possible. Currently, central server application allows for simultaneous use of the questionnaires in five different languages.

4.3. Summary

Studies on virtual autopsy in the last years formed practically a new subject in forensic medicine, namely forensic

cross-sectional imaging. After its implementation in forensic medicine and confirmation of its utility and feasibility, the next step shall be its validation and routine use. For the last, multiple case studies or close collaboration between forensic institutes are needed.

Considering the presently infrequent availability of the CT or MRI scanners for forensic institutions and the varying case material in forensic medicine, an evaluation of benefits and limitations of post-mortem imaging regarding certain forensic features by a single institution is circumstantial and also not reasonable. A centralized database allowing inter alia for international forensic and also trans-disciplinary collaborations can provide important support for forensic-radiological casework and research.

Such a web-based database with questionnaires to all body regions and tissues was created (Fig. 4). To the main goals of the database belongs the parallel documentation of forensic-radiological and pathological findings of the body. This will allow for direct comparisons between post-mortem cross-sectional radiology and the conventional autopsy data, thus for calculating the accuracy of each method and for considering which of them is the gold standard for a certain forensic finding. Based on documented cases the extensive comparison of both methods regarding different forensic features can be performed and the autopsy can be scrutinized as the gold standard examination method in forensic medicine.

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